PHASE III: FULL SCALE DEVELOPMENT

Step 15.0 Conduct HF/S Detail Design

Objective:

- Provide guidance to conduct HF/S detail design.

Inputs:

- Results of prior analyses.

Outputs:

- HF/S design concepts and criteria

15.1 Identify Human Machine Interface Design Constraints --This sub-step is concerned with identifying human-machine interface (HMI) requirements, and conducting analyses and studies to assess HMI concepts. The activities to be conducted are described below.

15.1.1 Conduct maintenance analysis - This activity will identify maintainer tasks and task requirements and requirements associated with design of maintainer - machine interfaces. These include: workspace design and layout; LRU design for accessibility, removal/ replacement, and handling diagnostic display design; design of alerts and alarms; technical documentation accessibility, readability and usability; new maintenance skills, and maintenance training methods, materials and media requirements. The HF/S Design Approach Document for maintenance (DAD - M) will receive inputs from Logistics Support Analysis Report (LSAR) data sheets. LSAR Data Sheet A, operations and maintenance requirements, and expected maintenance workloads. The HF/S DID document will also receive inputs from Data Sheet B, item reliability and maintainability characteristics, specifically: mean time to repair estimates; maintainability considerations; failure modes, effects and criticality data; failure symptoms; task analysis results; and the maintenance concept. The HF/S DAD- M document will provide inputs to:

- LSAR Data Sheet C -task analysis summary, specifically:
  - skill specialty codes
  - task duration estimates
- LSAR Data Sheet D - maintenance and operator task analysis
  - sequential task descriptions
  - task work areas
  - equipment accessibility requirements
  - identified maintainer-machine interfaces
- LSAR Data Sheet E-support and test equipment or training material description and justification

        - drawings or photographs of each equipment having a maintainer interface
        - equipment installation requirements
        - technical documentation requirements
        - diagnostic readout requirements
        - additional skill requirements
        - installation factors-constraints for accessibility
        - maintenance procedures and decision criteria
    - LSAR Data Sheet G -skill evaluation and justification
        - revised skills -by duty position
        - additional skill requirements
        - physical and mental requirements
        - educational qualifications
        - additional training requirements.
    - Define Maintainability Design Requirements
        - review LSA maintenance data and requirements
        - identify each item of equipment requiring maintenance
            - specify as organizational or intermediate
            - specify maintenance actions required
            - identify requirements associated with the conduct of maintenance actions
        - complete maintenance task analyses for selected items
        - develop maintainability design requirements
            - maintenance information requirements
            - design for accessibility
            - equipment arrangement to facilitate maintenance
            - procedures-number and simplicity
            - troubleshooting diagnostics and decisions
            - skill levels and maintenance training
            - equipment design for maintainability
            - allocation of maintenance responsibility to man or machine
            - equipment installation requirements
            - requirements for special tools and support equipment
            - job aid requirements
            - communication requirements
            - facility design requirements
            - safety design requirements
    - Conduct Analyses to Develop Maintainability Design Concepts
        - identify maintainability design approaches in predecessor/baseline systems
        - identify maintainability design problems from the fleet feedback system
        - conduct studies and simulations
            - to resolve human performance issues
            - to develop maintainability design concepts
            - to evaluate concepts
        - develop HF/S design concepts
            - equipment design concepts to facilitate maintenance
            - maintenance information concepts
            - role-of-man versus automation concepts
            - job performance aiding concepts
            - facility design concepts to facilitate maintenance

        - conduct tradeoffs-select concepts
        - integrate selected concepts across maintenance requirements
    - Conduct Analyses to Support Development of Maintainability Design Criteria
        - develop HF/S maintainability design criteria
        - prepare LSAR inputs
        - prepare the HF/S design approach document-maintainability
    - Conduct analyses and studies to support the development of design requirements and approaches for:
        - annunciators and alarms
        - fault detection
        - fault diagnosis
        - troubleshooting decision aiding
        - removal/replacement
        - test, measurement, and diagnostic equipment
        - built in test and automatic test equipment
        - tool and test sets
        - equipment identification and marking
    - Conduct analyses to establish the role of man vs automation in maintenance activities
    - Develop design requirements for maintenance access and workspace
    - Develop design requirements governing equipment arrangements
    - Assess maintainer error potential and develop approaches to reduce the likelihood of error
    - Assess potential time to repair problems and develop approaches to reduce the MTTR
        - Conduct access studies
            - develop access requirements
            - prepare mockups of areas to be accessed
            - verify accessibility through controlled access studies
        - Provide inputs to the RMA analysis
            - identify the extent to which HF/S reduces *time to repair*. HF/S will reduce time to repair, time to reconfigure system components, and time to conduct tests. HF/S application reduces the time required for these activities through a more usable design, troubleshooting practices which take into account human decision making capabilities, improved maintenance access, simplified design concepts, improved alarms and annunciators, and improved procedures.
            - identify the extent to which HF/S reduces the incidence of maintainer *human error*. HF/S methods for reducing human errors include a) the imposition of HF/S and safety design standards, b) reliance on test and evaluation procedures, as interviewing subject matter experts, examination of work samples, observation of task sequences, and use of simulation, and c) investigation of critical incidents to understand the dynamics and etiology of human error. HF/S studies have found that application of HF/S /HF/S reduces the probability of human error by up to 75%.
            - identify the extent to which HF/S reduces maintainer *workload* levels required. Cognitive workloads are reduced through improved diagnostics, procedures, and decision aids. The
            - identify the extent to which HF/S reduces the *skills* required on the part of maintenance personnel, which results in a reduction of maintenance

training burden. Skill/training reductions result from design simplification, procedures improvement, and use of decision aids.
        - identify the extent to which HF/S improves maintenance *procedures*. Difficulties involved with providing adequate procedural guidance have been well documented. Such difficulties arise from insufficient amounts of information being contained in the procedure, from factual omissions in the procedure, from direct errors in the procedure, and from inappropriate organization and layout of the procedure.
        - identify the extent to which HF/S enhances maintainer *safety and health*, through hazard identification, design to eliminate or control hazards, and design of jobs to reduce the incidence of cumulative stress trauma, such as carpal tunnel syndrome.
        - identify the extent to which HF/S results in increased maintainer *productivity*. HF/S application enhances maintainer productivity by ensuring that equipment is usable, that workloads are reasonable, that stress associated with the job is reduced, and that the worker is safe. The inclusion of a concern for HF/S in CG system design for maintainability will address the role of personnel versus automation conduct of maintenance tasks, and will enable workers to work faster with a heightened level of job satisfaction and personnel safety.
        - identify the extent to which HF/S enhances system *affordability* and reduces the life cycle costs of a system by reducing costly errors and accidents, reducing system downtime by reducing time to repair, reducing training time through task simplification and use of on-line decision aiding, and reducing the numbers and skills of personnel required.
        - identify RMA requirements
        - conduct an analysis to determine if RMA requirements will be met
        - identify RMA problem areas
    - Conduct analyses to integrate maintainability design requirements and approaches

15.1.2 Conduct MMI analysis

- Analyze Man- Machine Interface Requirements
    - review operability design concepts
    - for each task listed in the task analysis, identify control requirements:
        - control functions
        - type of control-continuous or discrete
        - associated display function
        - control priority
        - accuracy requirements
        - time to respond requirements
        - frequency of use
        - duration of use
        - feedback requirements
        - number of inputs
    - for each task, identify display requirements
        - display functions

        - information to be displayed
        - associated control functions
        - type of display- analog or digital
        - display priority
        - display accuracy requirements
        - display frequency of use
        - display duration of use
        - number of tasks requiring displayed information
        - format requirements
    - for each task, identify control-display arrangement requirements
        - control-display priorities
        - operational sequences
        - functional grouping requirements
        - control-display integration requirements
        - control integration requirements, across tasks
        - display integration requirements, across tasks
    - for each task identify control -display identification -coding requirements
        - labeling requirements
        - panel marking requirements
        - control coding
        - display coding
- Conduct Analysis to Develop Man-Machine Interface Design Concepts
    - identify human- machine interface approaches implemented in predecessor or baseline systems, and identify problems with each approach from the lesson learned
    - describe alternate human -machine interface concepts for specific missions, conditions and task sequences
    - conduct studies and simulations to develop alternative concepts and to evaluate the effectiveness of human-machine interface concepts
    - tradeoff alternate concepts and select human-machine interface design approach for selected sequences
    - develop HMI concepts for space and machinery arrangements
- Conduct Analysis to Develop Human -Machine Interface Design Criteria
    - integrate selected approaches over all sequences
    - develop design criteria for selected concepts

15.1.3 Conduct Human-Computer Interface (HCI) analysis

- Develop Human-Computer Interface Design Requirements
    - review operability/maintainability concepts
    - identify requirements for man -computer interface
        - data access-retrieval dialogues
        - command modes
        - retrieval modes
        - data entry devices
        - displays and display formats
        - requirements for page composition
        - requirements for data compilation

        - requirements for dedicated versus multi-function displays
        - data designation requirements
        - help mode requirements
        - display transparency requirements
        - direction -cueing requirements
        - Human-computer interaction requirements
      - identify tasks requiring a Human-computer interface
      - identify specific interfaces
        - input-entry devices
        - data designation devices
        - data modification -update devices
        - display characteristics
        - multi -display integration
        - multi-page integration
      - identify design requirements for each interface for each task
  - Conduct Analyses to Develop Human-computer Interface Concepts
    - identify man -computer interface approaches in predecessor and baseline systems
    - identify problems with existing Human-computer interface using the ECA
    - conduct studies and simulations to develop and evaluate alternate Human-computer interface concepts
    - develop alternate Human-computer interface concepts
    - conduct tradeoffs
  - Conduct Analyses to Develop Human-computer Interface Design Criteria
    - integrate selected concepts across task sequences
    - develop design criteria for Human-computer interface

15.1.4 Conduct facility/arrangements analysis

  - Identify Facility Design Issues
    - Workspace-facility design requirements
      - workspace dimensions- safety requirements
      - equipment arrangement requirements
      - compartment arrangement requirements
      - space configuration requirements
        - free volume
        - traffic patterns
        - manning levels
        - layout arrangement
        - use frequency/duration
        - growth potential
        - relationship to other spaces
      - material requirements
        - furnishings
        - equipment operability
        - equipment maintainability
        - equipment safety
        - decor

        - environmental requirements
            - expected levels
            - environmental controls
    - HF/S facility requirements inputs to Data Sheet F of the LSAR.
- Develop Workspace and Facility Design Requirements
    - review task analyses to identify where tasks must be performed
    - allocate tasks and task performance requirements to facilities
- Identify facility user functions and associated facility requirements
    - enter facility
    - prepare the facility
    - configure the facility
    - inhabit the facility
    - access workspace
    - access procedures, documentation, equipment
    - access consoles and panels
    - perform facility operations
    - perform tests within facilities
    - perform facility maintenance-arrangement of equipment and components
    - perform locomotion in facility
    - perform cargo transfer within facility
    - respond to alarms
    - communicate within facility
    - communicate with personnel exterior to the facility
    - use emergency equipment in the facility
    - facility emergency egress
- Review facility design concepts in predecessor/baseline systems
- Review facility design problems from field feedback
- Conduct walkthrough of task sequences
    - using predecessor facility
    - using facility mock-ups
    - using scaled down models
    - using computer simulations
    - using CAD
- Develop alternative facility concepts
- Integrate facility concept selection for different task sequences
- Conduct analyses to develop facility design criteria

15.1.5 Conduct procedures/documentation analysis

- Develop Procedures/Documentation requirements
    - review operability design concepts
    - identify requirements for additional information associated with each operational/ maintenance task
    - identify approaches for support information in predecessor and baseline systems
    - identify information presentation design requirements
- Conduct Analyses to Develop Procedures/Documentation Concepts
    - identify information presentation concepts

        - Conduct studies and simulations to develop alternative concepts and to evaluate competing procedures and documentation information presentation concepts
        - conduct tradeoffs of alternate concepts
    - Conduct Analyses to Develop Documentation Design Criteria
        - integrate selected concepts over missions, conditions and sequences
        - develop design criteria for selected concepts

15.1.6 Conduct communications analysis

- Develop communications measures of effectiveness to assess design concepts and criteria for:
    - operability design
    - intelligibility
    - message acceptability
    - station characteristics
- Define and analyze communications design requirements
    - requirements for sufficient communication devices/systems to be provided for all communication
    - define communications system design requirements based on link analyses and operational sequence analyses
    - define communications system design requirements of each device based on CG, industry, and international standards and guidelines
- Define and analyze communications intelligibility requirements
    - conduct speech intelligibility evaluations for devices used in similar systems
    - apply the data from these evaluations in the design of devices
    - conduct speech intelligibility evaluations for the new system
    - assess acceptability of message samples, noise conditions, and device fidelity acceptable in terms of HF/S standards
- Define and analyze communications message acceptability requirements
    - standardize messages
    - define messages based on constrained language, controlled syntax, and restricted message content
    - code message priority
    - conduct error likelihood analysis to identify potential errors in message transmission
- Define and analyze communications station characteristic requirements
    - conduct walkthroughs of communications traffic used in identifying station characteristics
    - consider mobility requirements on the part of users
    - consider user clothing conditions
    - define network requirements based on link analysis
    - describe range of potential environments (especially noise and vibration) considered in design of stations
- Integrate communications requirements

15.2 Conduct Detailed Human-Machine Interface Design for Operability -The aspect of a system which addresses design to support human interaction with information is designated as the human-machine interface (MMI). MMI is defined as encompassing all elements of a system or

an information management system with which the human user must interact. System elements which impact MMI include workstations, I/O hardware, software, data bases, networks, computation systems, peripheral devices, communications systems, and software engineering environments. MMI can be conceptualized as including: displays, displayed information, display characteristics, display formats, integration of displays, labels, instructions, alarms, symbology and graphics, decision aids, decision support systems, input devices, data designation and manipulation devices, user interface language, expert systems and knowledge-based systems, interactive user-computer dialogues, command language, command modes, controls and controllers, control systems, control and display arrangements, communications, workspace layout, workspace environment, help features, embedded training, intelligent tutoring systems, and procedures.

A critical need exists for standardization of workstation human-machine interfaces. Before such standardization can occur, workstation MMI operability issues must be considered. MMI operability objectives include the following:

- reduce cognitive workloads,
- reduce training requirements and demands,
- reduce operator errors and effects of errors,
- reduce reaction/response time;
- enhance decision accuracy,
- enhance the understanding of the operational situation
- enhance overall human performance.

15.2.1 Develop operability human-machine interface (MMI) design concepts

- identify human-machine interface approaches implemented in predecessor or baseline systems, and identify problems with each approach from the fleet feedback system
- describe alternate human-machine interface concepts for specific missions, conditions and task sequences
  - develop display integration concepts
  - develop feedback concepts
  - develop display mode concepts
  - develop large screen - group display concepts
  - develop computer display concepts
  - develop special display concepts
  - develop information integration levels
  - develop role-of-man in the control system concepts
  - develop special control design concepts
  - develop equipment arrangement concepts
  - develop workspace layout concepts
  - develop control-display integration concepts
  - develop control console integration concepts
  - develop job performance aiding media concepts - hard copy versus electronic display
  - develop decision aid concepts
  - develop labeling concepts

        - develop display coding concepts
    - conduct studies and simulations to develop alternative concepts and to evaluate the effectiveness of human-machine interface concepts
        - identify tasks associated with controls and displays
        - ensure that operator performance capability has been demonstrated to meet performance requirements
        - develop designs based on human-machine studies and walkthroughs
        - develop details of the design consistent with MIL-STD-147.2C
        - perform error likelihood analyses to identify types of expected performance errors associated with the design approach
        - develop operational procedures
        - develop concepts for control and display arrangements based on sequence of use, priority and functional grouping
    - Conduct tradeoffs
        - describe design alternatives
        - describe tradeoff criteria
        - complete tradeoffs
    - Describe the design concepts for operability
        - describe concepts for enhanced visual systems to extend detection and engagement ranges
        - describe concepts for target engagement decision aids
        - describe concepts for target designation techniques
        - describe concepts for predictive displays
        - describe concepts for integrated test and training techniques
        - describe concepts for enhancement of visual envelopes
        - describe concepts for integrated displays
        - describe concepts for situation displays
        - describe concepts for navigation display concepts
        - describe special sensor concepts
        - describe workstation concepts
        - describe workload distribution concepts
        - describe task allocation concepts
        - describe control concepts
        - describe display concepts
        - describe communication concepts
        - describe equipment arrangement concepts
        - describe integrated display concepts

15.2.2 analyze requirements, concepts and criteria for workstation design for operability

- design of human-machine interfaces to reduce errors
- design of human-machine interfaces to reduce workloads
- design of human-machine interfaces to simplify tasks
- design of procedures
- design of communications

15.3 Conduct Detailed Human-machine Interface Design for Maintainability -Maintainability design requirements include information requirements, design for accessibility, equipment

arrangement to facilitate maintenance, procedures, troubleshooting diagnostics and decisions, skill levels and maintenance training, equipment design for maintainability, allocation of maintenance responsibility to man or machine, equipment installation requirements, requirements for special tools and support equipment, job aid requirements, communication requirements, facility design requirements, and safety design requirements

15.3.1 Develop maintainability design concepts

- 15.3.1.1 Define Maintainability Design Requirements
  - review LSA maintenance data and requirements
  - identify each item of equipment requiring maintenance
    - specify as organizational or intermediate
    - specify maintenance actions required
    - identify requirements associated with the conduct of maintenance actions
  - complete maintenance task analyses for selected items
  - develop maintainability design requirements
    - maintenance information requirements
    - design for accessibility
    - equipment arrangement to facilitate maintenance
    - procedures - number and simplicity
    - troubleshooting diagnostics and decisions
    - skill levels and maintenance training
    - equipment design for maintainability
    - allocation of maintenance responsibility to man or machine
    - equipment installation requirements
    - requirements for special tools and support equipment
    - job aid requirements
    - communication requirements
    - facility design requirements
    - safety design requirements
  - Develop Maintainability Design Concepts
    - identify maintainability design approaches in predecessor/baseline systems
    - identify maintainability design problems from the lessons learned
    - conduct studies and simulations:
      - to resolve human performance issues
      - to develop maintainability design concepts
      - to evaluate concepts
    - develop HF/S design concepts
      - equipment design concepts to facilitate maintenance
      - maintenance information concepts
      - role-of-man versus automation concepts
      - job performance aiding concepts
      - facility design concepts to facilitate maintenance
      - conduct tradeoffs - select concepts
      - integrate selected concepts across maintenance requirements
  - Develop Maintainability Design Criteria
    - develop HF/S maintainability design criteria

- prepare LSAR inputs
- prepare the HF/S design approach document-maintainability

15.3.2 analyze requirements, concepts and criteria for the workstation design for maintainability

- design for accessibility
- design of troubleshooting diagnostics design of maintenance human-machine interfaces

15.4 Conduct Detailed Human-machine Interface Design for Supportability - The acquisition strategy will identify resource requirements and explicit planning to achieve these objectives. The acquisition strategy will emphasize: early identification of support and supportability requirements including any planned use of warranties; evaluation of alternate support concepts and techniques to reduce cost and support risk; and identification of test articles to conduct reliability, maintainability, and logistics supportability test and evaluation.

Integrated logistics support efforts shall encompass the ten elements identified below:

- maintenance planning;
- workload and personnel;
- supply/support;
- support equipment;
- technical data including technical documentation;
- training and training support;
- computer resources support;
- facilities;
- packaging, handling, storage, and transportation;
- design interface.

Preliminary peacetime and wartime readiness objectives and thresholds will be established by KDP 2, Concept Demonstration Approval, and final objectives and thresholds will be established by KDP 3, Development Approval. The acquisition strategy will Identify resource requirements and include explicit planning for achieving these objectives. The acquisition strategy will emphasize:

(1) Early identification of support and supportability requirements including any planned use of warranties,

(2) Evaluation of alternative support concepts and techniques to minimize cost and support risks,

(3) Identification of test articles needed to conduct reliability, maintainability, and logistics supportability test and evaluation, and

(4) Contractor incentives for timely attainment of support related design objectives.

Integrated Logistics Support Plan. The management approach, decisions, and plans

associated with logistics planning efforts will be documented in an Integrated Logistics Support Plan (ILSP). This plan will:

(1) be the basis for coordinating logistics planning efforts and ensuring that each one of the integrated logistics support elements is addressed and integrated with the other elements throughout the program; and

(2) include planning for deployment and post-production support.

Computer Resources Support. The Integrated Logistics Support Plan will be prepared in close coordination with the Computer Resources Life-Cycle Management Plan and will directly reference that plan. For computer resources or software that will be transferred to logistics organizations for maintenance or modification, areas to be addressed for software support will include special skills, facilities, software tools, and special purpose computer requirements.

Planning Factors. Integrated logistics support planning must be focused at the level at which support resources must be integrated to affect maintenance (i.e., the level at which specific repair or maintenance will occur). This is usually at the subsystem or below. The Integrated Logistics Support Plan will reflect this focus.

Logistics Support Analysis. A tailored logistics support analysis (LSA) will be used iteratively throughout the acquisition program as an integral part of the systems engineering process.

(1) The logistics support analysis process will be used to:

- Develop and define supportability related design factors.
- Ensure the development of a fully integrated system support structure.

(2) This process will incorporate, but not duplicate, analysis and data required by other functional disciplines.

(3) The logistics support analysis record (LSAR) will be established for recording, processing, and reporting supportability and support data and will be used as the definite source for this data.

Manpower, Personnel, Training, and Safety. Manpower, personnel, training, and safety are essential design, human systems integration, and support considerations. They will be given explicit attention early in the acquisition process.

15.4.1 Identify procedures/documentation/decision aiding design concepts

- Develop Procedures/Documentation requirements
  - review operability design concepts
  - identify requirements for additional information associated with each operational/ maintenance task
  - identify approaches for support information in predecessor and baseline

systems
- identify information presentation design requirements for information format
- identify information presentation design requirements for information source
- identify information presentation design requirements for information quantity
- identify information presentation design requirements for information currency
- identify information presentation design requirements for information update rate
- identify information presentation design requirements for relationship to primary display

- Develop Procedures/Documentation Concepts
  - identify information presentation concepts
    - hard copy
      - text
        - manuals
        - page of text
      - checklists
        - hand held - other than text
          - special calculators
          - lookup tables
          - graphics
    - displays
      - electronic
        - dedicated
        - shared (time and space shared)
        - overlay
      - video - pictorial
        - fische
        - pictures
  - conduct studies and simulations to develop alternative concepts and to evaluate competing procedures and documentation information presentation concepts
  - develop tradeoff criteria from requirements
  - develop tradeoff criteria from predecessor system performance, availability, readability and cost
  - conduct tradeoffs
- Develop Documentation Design Criteria
  - integrate selected concepts over missions, conditions and sequences
  - develop design criteria for selected concepts

15.4.2 analyze requirements, concepts and criteria for the workstation design for supportability

- design of technical documentation
- design for handling and transportation

15.4.3 Develop training system design concepts

- conduct studies and analyses to develop training device concepts
- describe alternative training device concepts
  - develop concepts for type of media

        - information reception - knowledge based
        - skill acquisition - performance based
    - develop concepts for type of implementation
        - part task - stand alone
        - full task - stand alone
        - embedded
    - develop concepts for training application
        - generic to a class of systems
        - system specific
    - develop concepts for training approach
        - individualized - self-paced
        - demonstration
        - instructor interaction
        - computer interaction
    - conduct tradeoffs of alternative concepts
    - integrate selected concepts across training objectives
    - develop training device design criteria

15.5 Conduct Detailed Human-machine Interface Design for Habitability -Habitability design involves specifying workspace free volume, environmental effects, traffic patterns, workspace layout, facility compartmentalization, and adequacy of the design for habitability. The HF/S engineering concepts to be developed will address the major user-machine and user-facility interface issues. HF/S engineering concepts will either be developed or will reflect an assessment of architectural/engineering design concepts from a HF/S engineering point of view. Specific concepts will include the following:

- Compartmentalization concepts - room occupancy and utilization
- Arrangements concepts - traffic patterns
- Accommodations concepts - compartment equipment and fixtures
- Safety concepts - concepts for hazard avoidance, guarding, or warning
- Facility maintenance concepts - workspace and access space required
- Equipment maintenance concepts - maintenance access
- Environmental control concepts
- Communications concepts
- Supply/support concepts

15.5.1 review task analyses to identify where tasks must be performed

- allocate tasks and task performance requirements to facilities
- identify facility user functions
- identify facility requirements by function
    - identify requirements for entering the facility
        - access location requirements
        - access identification requirements
        - access dimension requirements
        - access safety requirements
    - identify requirements for preparing the facility
        - control of lighting requirements

    - control of temperature and humidity
    - control of ventilation
- identify requirements for configuring the facility
    - free volume requirements
    - arrangement of locomotion spaces
    - arrangement of cargo transfer spaces
    - arrangement of work space
- identify requirements for inhabiting the facility
    - lighting requirements and constraints
    - noise constraints
    - vibration constraints
    - temperature/humidity requirements and constraints
    - ventilation requirements and constraints
    - radiation constraints
    - human needs
- identify requirements for accessing a workspace within the facility
    - access standardization requirements
    - access illumination
    - access safety
- identify requirements for accessing procedures, documentation, equipment
    - identify storage area
    - access storage requirements
- identify requirements for accessing consoles and panels
    - console-panel arrangements requirements
- identify requirements for performing facility operations
    - furnishing requirements
    - support equipment requirements
    - storage space requirements
    - workspace requirements
    - environmental factors
- identify requirements for performing tests within facilities
    - test point location and arrangement
    - access and operation of test equipment
    - communications requirements
    - visual access of test personnel
    - automatic test equipment requirements
- identify requirements for performing maintenance in the facility
    - arrangement of equipment and components
    - location and access of tools
    - component identification
    - methods of indicating maintenance in programs, e.g., tag out
    - component handling, moving, lifting equipment
    - component design for repair in place
    - component location for maintenance access
    - component design for ease of removal-replacement
    - component design for ease of calibration, adjustment
    - component design for ease of inspection, monitoring
    - location and arrangement of service points, replenishment accesses

        - location and access to spaces
        - design and location of alignment aids for insertion, installation, replacement
        - design and location of precautions, warnings and special instructions
    - identify requirements for performing locomotion in the facility
        - traffic pattern requirements
        - route characteristics and dimensions
        - manning requirements
    - identify requirements for performing cargo transfer within the facility
        - cargo handling and transfer requirements
        - control requirements
        - material handling equipment requirements
    - identify requirements for responding to alarms in the facility
        - signal coding requirements
        - signal intensity
        - location and arrangement of signals
    - identify requirements for communicating within the facility
        - visual access requirements
        - speech communication requirements
        - noise levels
        - communications media requirements
    - identify requirements for communicating with personnel exterior to the facility
        - communications equipment location and access
        - speech intelligibility limits
        - noise levels
    - identify requirements for accessing and using emergency equipment in the facility
        - standardization of fire fighting equipment
        - protective clothing storage
        - special instructions for emergency equipment operations
        - breathing apparatus requirements
        - body protective clothing requirements
        - compatibility of protective clothing with operations
    - identify requirements for egressing the facility in an emergency
        - location of egress
        - egress illumination

15.5.2 Review facility design concepts

- review facility design concepts in predecessor/baseline systems
- review facility design problems from fleet feedback system
- conduct walkthrough of task sequences
    - conduct walkthrough using predecessor facility
    - conduct walkthrough using facility mock-ups
    - conduct walkthrough using scaled down models
    - conduct walkthrough using computer simulations

15.5.3 develop alternative facility concepts

15.5.4 conduct tradeoffs

15.5.5 integrate facility concept selection for different task sequences

15.5.6 develop facility design criteria

15.6 Conduct Detailed Human-Machine Interface Design for Usability -The development of detailed MMI design for usability will focus on prototyping MMI concepts to assess and reduce the risks associated with integrating available and emerging HF/S technologies into a system design approach to satisfy a validated mission need. Test and evaluation of prototypes will confirm the feasibility of specific design approaches relative to its ability to satisfy the mission need and achieve minimum acceptable operational performance requirements within affordability constraints. Prototyping will be used to assess cost and performance tradeoffs.

In test and evaluation planning, all system components should be addressed including human interfaces.

15.6.1 Develop User-Computer Interface (UCI) design concepts

- review operability/maintainability concepts
- identify requirements for UCI
- identify tasks requiring a UCI
- identify requirements for specific UCI features
  - identify requirements for data access - retrieval dialogues
  - identify requirements for command modes
  - identify requirements for retrieval modes
  - identify requirements for data entry devices
  - identify requirements for displays and display formats
  - identify requirements for page composition
  - identify requirements data compilation
  - identify requirements for dedicated versus multi-function displays
  - identify data designation requirements
  - identify help mode requirements
  - identify transparency requirements
  - identify direction - cueing requirements
  - identify user-computer interaction requirements
- Develop User-Computer Interface Concepts
  - identify user-computer interface approaches in predecessor and baseline systems
  - identify problems with existing user-computer interface using lessons learned
  - conduct studies and simulations to develop and evaluate alternate user-computer interface concepts
  - develop alternate user-computer interface concepts
  - develop input/output concepts
  - develop data access - retrieval dialogue concepts
  - develop user-computer interaction concepts
  - develop command mode concepts
  - develop data base management concepts

- conduct tradeoffs
- select design concepts for man-computer interface

15.6.2 Develop workstation design requirements

- Review descriptions of the workstation requirements
- Identify requirements to develop new workstations, use NDI, or improve existing workstations
  - identify acquisition requirements
    - standard acquisition
    - streamlined or accelerated acquisition
  - identify requirements for NDI
    - commercial off-the-shelf (see Step 43)
    - military off-the-shelf
  - identify requirements for product improvements
- Identify specific requirements for HF/S input into workstation design
  - identify requirements for determination of the roles of man in system operation and maintenance
  - establish an early focus on potential users
  - identify W/S User Cognitive Strategies
    - Mental models - Mental models refer to the users cognitive representation or model of the workstation .
    - User Models - The corollary of mental models are user models. A user model is the workstation 's model of the person or user. While mental models are most important during initial design, user models are best applied during testing and evaluation of a new workstation.
  - develop an interactive relationship with users
- Define Workstation Objectives and Functions
  - identify what should the workstation do - functions which the workstation system will perform
  - identify how should the workstation do it
    - identify applicable HF/S criteria - five measurable HF/S criteria which must be considered before the design goals for the human interface can be specified:
      - Time to learn specific functions
      - Speed of task performance
      - Rate of user errors
      - Subjective user satisfaction
      - User retention of skills over time.
  - identify who will use the workstation address issues of physical and cognitive fit
    - Physical Fit - The number of persons physically interacting with the displays (i.e., performing control actions), and the number of persons simply viewing the displays should be identified.
    - Cognitive Fit - required information displayed at the necessary level of abstraction based on users existing mental models and the anticipated user models
  - identify where will the workstation be used
    - Facility or facilities in which the proposed workstation will be used

    - Environment in which the workstation will be located
- identify when will the workstation be used
    - Different presentation modes can be used to convey the same information, depending on when the workstation is used
    - User should be provided with no more information than that which is necessary to perform his job at that particular point in time.
- Conduct Function Analysis
    - identify functions
    - construct functional flow block diagrams
- Allocate Functions
    - hypothesize design solutions
    - identify mandatory allocation considerations
    - identify goodness of fit considerations
    - identify utilitarian/cost considerations
    - identify intrinsic considerations
        - provide Cognitive Support in response to specific questions, such as:
        - could displays or other sources of information be provided to furnish all the information needed?,
        - can a work sequence be established so that the human will maintain an adequate mental model of the workstation and its conditions by being actively involved in controlling or approving the key workstation changes?,
        - could the human operator be given sufficient workload to ensure alertness?,
        - could the functions be allocated dynamically to either human or machine depending on which can best accommodate the increased workload at the time the function is required?
    - test hypothesis
- Conduct cognitive task analysis - Cognitive task analysis is a process by which a cognitive task is described and examined, and its characteristics (e.g., workload, information requirements, control requirements) are identified. The purpose of conducting a cognitive task analysis is to: (1) identify the actions the equipment and user must take in order to accomplish user cognitive functions and, (2) provide a basis in which the tasks identified can be analyzed to determine what information is required in order to support these tasks.
    - identify Cognitive Tasks as the tasks required of the user to support each function or subfunction which place demands on the cognitive capabilities of the user
    - identify information requirements - Once the function supporting cognitive tasks have been identified, the information requirements for each task must be identified. Any required information which is not available from the workstation must come from some other source such as training, experience, communication systems, or procedures. Specific information requirements include:
        - How many dimensions does this task depend on (e.g., speed, height, pressure)?,
        - How many variables does this task depend on?,
        - How many samples of each variable are needed for this task?,

        - What is the primary function of the information (alert, provide detailed information, etc.)?
        - Does the task require qualitative or quantitative information?
        - If qualitative information is required, will it be used for alert, status, prediction or pattern recognition?
        - If quantitative information is required, should it be exact, or will approximate or relative information be sufficient?
        - For quantitative information: what is the range of the variable, what is the required level of accuracy for using this information, how quickly must this information respond to control actions, and is the information to be used in an absolute or relative manner?,
        - How important is this information relative to other information?
        - What are the temporal relationships among this information requirement and other information requirements?
- Select Display Elements - The goal of this step is to associate each required item of information identified during the task analysis with some element in a picture in order that it may be displayed.
    - identify display elements other than icons
    - Develop icon design concepts - In the population-stereotype or symbol production technique, users are asked to draw symbols for the concepts in question. Drawings are subsequently classified and subjected to an extensive testing program.
    - Generate Symbols - A questionnaire should be developed and distributed to the potential user population asking them to generate a single symbol for each function identified. The subject's task is to generate a hand drawn picture that he or she thinks would best represent the concept or function in question.
    - reduce pictures - attach a short verbal descriptor to each picture which should be checked by at least three independent judges for consensus, and then listed in tabular format within each functional context.
    - tally responses - The number of pictures drawn for each verbal descriptor should be tallied
    - verify stereotypes
        - a good symbol should be simple, discriminable from other members of the set, and meaningful.
        - Meaningfulness Verification - an independent sample of users should be presented with the proposed symbols and asked to write down the name of the symbol.
        - a magnitude estimation technique may alternatively be used, whereby a candidate set of symbols for each function is arranged in a circular array on a single page. The subjects are asked to make a magnitude estimate of the informativeness of each candidate symbol
    - select symbols
- Construct Display Pages
    - assemble all display elements into hand drawn display pages or screens.
    - define screen content - In considering screen content, there are interrelated functions which govern an acceptable display - adequacy, cohesiveness and necessity.

- Adequacy - content of a display page should be adequate or sufficient to support an entire function, subfunction, task or information requirement.
- Cohesiveness - display elements should be related to each other in the mind of the potential user. A cohesive set of picture elements will create a context within which a great number of elements can be effectively monitored. If display elements are unrelated and do not present a cohesive picture, the user will be unable to effectively monitor as many elements, typically only three to five.
- Necessity - each element included on the display page should be necessary to either convey information directly, or to create cohesiveness among other elements.

  - define screen organization - Once the content of each display page has been tentatively determined display elements must be organized into some logical configuration.
    - Organization Guidelines
      - If certain elements have clear priority over others, place them in prominent locations, such as at the top of the display page.
      - Take advantage of physical relationships that are known to the user.
      - Organize the elements from top to bottom and from left to right in the order that they will be used.
      - Take advantage of any existing user conventions or population stereotypes.
      - Establish a focal point in each picture that will attract the user's attention and serve as the logical starting point for viewing each picture.
      - Take advantage of any training artifacts that are likely to determine how the user will organize this information in his own mind.
      - Make the picture aesthetically pleasing to view.

- Conduct paper and pencil walkthrough - Using checklists developed from design guideline handbooks - identify any major HF/S deficiencies that might compromise understandability or effectiveness of the proposed displays. Walkthroughs addressing understandability deal with content density, content integration, format orientation, and cognitive fidelity.
  - describe content density - density refers to the total amount of visual information and noise that is present on a display page.
  - describe content Integration - integration pertains to how well the elements of a display page fit together to form an integrated presentation of information.
  - describe format orientation - pertains to the ability of the display format to organize and highlight meaningful information.
  - describe cognitive fidelity - pertains to how well the page of information matches the user's mental model of the workstation
- Define Display Relationships
  - determine user needs - Picture structure should define the relationships between the pictures being viewed and the available alternatives not being

viewed.
    - identify structural requirements
- Mockup the interface - the scale drawings are turned into a working prototype of the proposed interface. The interface can be simulated or mocked-up using the procedures of rapid prototyping or user derived interfaces.
    - conduct rapid prototyping
        - Rapidly developing and simulating candidate interface configurations that can be easily modified after user evaluation.
        - produces software that is easy to modify.
        - enables the prototype to become the basis of the actual implementation.
    - user derived interfaces
        - Design features for human-computer interfaces are determined according to the responses or actions of the workstation user.
        - With facades, hidden operators intercept commands coming from the workstation user to create the illusion of a truly interactive session.
        - The procedure can be adapted to direct manipulation interfaces with the addition of a video camera and remote monitor.
- Perform User Acceptance Tests
    - one-to-one evaluation--This is an informal evaluation in which a potential user sits down with one of the workstation designers and attempts to use the workstation . During this stage there is more discussion with the designer as to difficulties being encountered then there is instruction on how to use the workstation Toward the end of the session, the user describes difficulties encountered in attempting to use the workstation .
    - small-group evaluation - During this next stage of evaluation, a group of potential users attempts to use the workstation with minimal intervention from the designers. Errors and difficulties are noted, and the workstation is redesigned in an attempt to remove these problems.
    - conduct field evaluation - In this next stage, which is also referred to as beta testing or site testing, the workstation is field tested to simulate the actual training and work environment.
    - conduct iterative redesign - Results of the user acceptance tests are fed back to the interface mockup step, and the entire process is repeated. This loop is the cornerstone of the iterative design approach in which the results of user acceptance tests define the redesign issues to be addressed in the next design iteration. This redesign is implemented by rapid prototyping procedures, and should continue until the desired workstation objectives and HF/S design goals are achieved.
- Conduct Experiments
    - Production software and accompanying documentation should be complete, and a series of observations are made under controlled conditions for the purpose of testing a hypothesis.
    - Comparative Evaluation- During comparative evaluation, comparisons are made to determine whether or not different workstation s or versions of the same workstation differentially affect the measures of interest.
    - Benchmark test - application of standardized set of tests to evaluate workstation or user performance on a set of core tasks.

- Absolute Evaluations- An absolute evaluation is concerned with assessing whether or not a workstation achieves a specified level of a particular measure.

15.6.3 analyze requirements, concepts and criteria for the workstation design for usability

- design of user-computer interfaces
- design of human-machine interfaces with expert systems
- design of procedures and documentation

15.7 Conduct Detailed Human-Machine Interface Design for Safety and Survivability

15.7.1 Prepare or update as applicable the System Safety Program Plan (SSPP) for Phase 3

- Review preliminary engineering designs
  - ensure that safety design requirements are incorporated
  - ensure that hazards identified during the earlier phases are eliminated or the associated risks reduced to an acceptable level.

15.7.2 Update documents and analyses

- Update system safety requirements in system specification/design documents.
- Update safety and health analyses
  - Perform or update the SSHA,
  - Perform or update the SHA
  - Perform or update the O&SHA and safety studies
  - Recommend any required design changes and control procedures.

15.7.3 Evaluate the interfaces between the test system configuration and personnel, support equipment, special test equipment, test facilities, and the test environment.

- Ensure that hazards identified by analyses and tests are eliminated or their associated risk controlled.
- Identify the need for special tests to demonstrate or verify system safety functions.
- Establish analyses, inspection, and test requirements for other contractors' or GFE/ GFP (hardware, software, and facilities) to verify prior to use that applicable system safety requirements are satisfied.

15.7.4 Participate in technical design and program reviews and present results of the SSHA, SHA and/or O&SHA.

- Identify and evaluate the effects of storage, shelf-life, packaging, transportation, handling, test, operation, and maintenance on the safety of the system and its components.
- Evaluate results of safety testing, other system tests, failure analyses and mishap investigations.
- Recommend redesign or other corrective action.

15.7.5 Review system safety design

- Identify, evaluate, and provide safety considerations or tradeoff studies.
  - Define concepts for guarding the hazard
  - Define concepts for labeling the hazard
  - Define concepts for alarming the hazard
  - Define concepts for training/procedures
  - Develop safety & health design criteria
- Review appropriate engineering documentation (drawings, specifications, etc.) to make sure safety considerations have been incorporated.
- Review logistic support publications for adequate safety considerations, and ensure the inclusion of applicable DOT, EPA, and OSHA requirements.
- Verify the adequacy of safety and warning devices, life support equipment, and personal protective equipment.
- Identify the need for safety training and provide safety inputs to training courses.

15.7.6 Provide system safety surveillance

- Provide support of test unit production
- planning for full-scale production and deployment.
- Identify critical parts and assemblies, production techniques, assembly procedures, facilities, testing, and inspection requirements which may affect safety
- Ensure that safety provisions are included in the planning and layout of the production line
- Ensure that adequate safety provisions are included in inspections, tests, procedures, and checklists for quality control of the equipment being manufactured
- Ensure that production and manufacturing control data contain required warnings, cautions, and special safety procedures.
- Ensure that testing and evaluation are performed on early production hardware to detect and correct safety deficiencies at the earliest opportunity.
- Ensure that minimum risk is involved in accepting and using new designs, materials, and production and test techniques.

15.7.7 Ensure that procedures developed for system test, maintenance, operation, and servicing provide for safe disposal of expendable hazardous materials.

- Identify any material or manufactured component when access to hazardous material will be required by personnel during planned servicing, teardown, or maintenance activities.
- Identify hazards from safety data developed in SSHAs, SHAs, and O&SHAs, and summarized in safety assignment reports for systems which are demilitarized and subject to disposal.

15.7.8 Prepare reports

- Prepare a summary report of the results of the system safety tasks conducted during Phase II to support the decision-making process.
- Tailor system safety program requirements for the production and deployment phase.

15.8 Review and approve engineering drawings depicting interfaces between system personnel and other system elements - Drawing reviews from a HF/S standpoint will focus on assessments of arrangements, human-machine interfaces and safety provisions depicted in the drawings. HF/S concerns will be translated into human-machine interface design issues to be addressed during systems engineering. This includes efforts to:

(a) Review human-system interface characteristics which require extensive cognitive, physical, or sensory skills; require complex manpower and training intensive tasks; or adversely affect human performance, identifying those elements that will be targeted for HF/S engineering changes.

(b) Review system safety and health hazard issues and lessons learned. Identify factors which result in frequent or critical human performance errors.

(c) Identify how such human-system interface characteristics and factors can be avoided or corrected through system design and HF/S engineering efforts.

In keeping with total system acquisition, test and evaluation will:

- Assess the integration of HF/S elements into the design hardware, software, and procedures;
- Include performance of operational tasks by typical users;
- Provide human performance and error rate data; and
- Verify HF/S design requirements have been satisfied.

15.8.1 Identify features to be evaluated in drawings

15.8.2 Define criteria to be used in the evaluations

- Identify criteria to evaluate human-machine Interfaces depicted in the drawings
  - are human-machine interface design approaches in compliance with the
  - provisions of MIL-STD 147.2?
  - are design techniques employed within accepted HF/S practice?
  - do design approaches depicted in the drawings exhibit potential problems
  - for human performance and safety?
  - are design approaches depicted in the drawings such that conduct of required
  - activities will require special skills?
  - are identification coding practices depicted in the drawings and are they
  - consistent across equipment and systems?
- Identify criteria to evaluate facility arrangements depicted in the drawings
  - are facility arrangements expected to impede information flow, traffic
  - patterns or interpersonal communications?
  - are provisions for access and egress adequate to accommodate emergency use?
  - are consoles and workstations designed to accommodate operators of all
  - expected body sizes and representative skill levels?
  - do workplace designs take into account expected extremes of environments
  - to be encountered at the workplace?

        - do equipment and facility designs take into account the potential donning, doffing, wearing and storage of individual protective ensembles?
        - are stowage locations identified as such, are they readily accessible, and are
        - they expected to provide adequate storage?
    - Identify criteria to evaluate maintenance workspace depicted in the drawings
        - are maintenance workstations identified as such and do they provide
        - sufficient space for safe and easy access to components for maintenance?
        - are items of equipment to be maintained by system personnel designed to
        - enhance maintenance?
        - are maintenance workstations designed to accommodate operators of all
        - expected body sizes and representative skill levels?
        - do maintenance workplace designs take into account expected extremes of environments to be encountered at the workplace?
        - are maintenance stowage locations identified as such, are they readily accessible, and are they expected to provide adequate storage?

15.8.3 Prepare checklists

15.8.4 Conduct evaluations

15.8.5 Identify potential problems

15.9. Integrate HF/S Design and Readiness Concepts - This step integrates the design, manning, and training concepts into a set of HF/S concepts for input to the system engineering process. The integration represents a description of the concepts highlighting the relationships among HF/S , MPT, and safety and health.

15.9.1 Resolve incompatibilities

- Conduct an HF/S comparability analysis
- Identify incompatibilities/inconsistencies
- Resolve incompatibilities/inconsistencies

15.9.2 Provide concept rationale

- Summarize HF/S design concepts
- Provide the basis for design decisions underlying the concepts
- Identify concept strengths and weaknesses

15.9.3 Identify design impacts

- Describe the system concept and HF/S design concept being assessed
- Describe operator/crew tasks with the concept - launch the NETWORK tool
- Describe high driver requirements associated with tasks and task sequences

15.9.4 Identify supportability impacts

- Describe the system concept and manning/role of man concept being assessed

- Develop a sequence of tasks to describe activities performed with the concept
- Conduct Workload Analyses
  - Determine workload levels for each position under each condition of readiness and selected operational scenarios
  - Identify workload overload and underload problems
  - Redistribute workloads
  - Conduct workload, manning and performance simulations using the event simulation
  - Identify the implications of each system concept and manning/role of man concept
  - Identify and describe feasible manning/workload reduction concepts
  - Identify impacts of design concepts on training

15.9.5 Describe workstation concepts

- review Man- Machine Interface Requirements - each workstation
- integrate workstation concepts and Man-Machine Interface Design Concepts
- integrate Man -Machine Interface Design Criteria
  - integrate selected approaches over all sequences
  - review design criteria for selected concepts
- integrate procedures/documentation concepts by workstation

15.9.6 Describe UCI concept

- Review User-Computer Interface (UCI) design requirements
- Conduct analyses to integrate User-Computer Interface concepts
- Conduct analyses to integrate User-Computer Interface design criteria

15.9.7 Describe arrangement/facility concepts

- Review facility design issues
- Review workspace arrangements and facility design requirements
- Review alternative facility concepts
- Integrate facility/arrangements concept for different task sequences
- Conduct analyses to integrate facility design criteria

15.9.8 Describe communications concepts

- Review communications requirements
  - message requirements
  - message frequency requirements
  - communication media requirements
- Integrate communications concepts
- Integrate communications criteria

15.9.9. Describe maintainability concepts

- Review maintainability design requirements

- Conduct analyses to integrate maintainability design concepts
- Conduct analyses to support integration of maintainability design criteria

15.9.10 Describe manning concept

- Integrate manning concepts over scenarios and missions
- Integrate operations and maintenance manning concepts
- Integrate crew utilization concept

15.9.11 Describe role of man concepts

- Review role of man concepts over different missions and scenarios
- Review workload data
- Conduct system level workload assessments

15.9.12 Describe training concepts

- Review task complexity and skill estimates
- Review training concepts
- Integrate training concepts

15.9.13 Describe training device concepts

- Conduct analyses to integrate training device requirements
  - identify training system requirements in terms of
    - training objectives
    - training method requirements by training objectives
    - training measurements requirements by training objectives
    - training material requirements by training objectives
    - training media requirements by training objectives
    - training management requirements
  - identify training device design requirements
    - training objectives addressed
    - information reception media
    - skills acquisition media
    - fidelity levels
    - display formats
    - range of conditions
    - use of augmented feedback
    - use of prompting and cueing
    - use of branching-programming
    - degree of flexibility to different system configurations
    - data acquisition and recording requirements
    - embedded training requirements
  - review training devices approaches implemented in predecessor/baseline systems
  - identify problems with existing training devices for selected training objectives
  - conduct studies and analyses to develop training device concepts

- Describe training device concepts
  - type of media
    - information reception
    - knowledge based
    - skill acquisition
    - performance based
  - type of implementation
    - part task
    - full task
    - embedded
  - application
    - generic to a class of systems
    - system specific
  - training approach
    - individualized-self-paced
    - demonstration
    - instructor interaction
    - computer interaction
- conduct tradeoffs of alternative concepts
  - integrate selected concepts across training objective
  - develop training device design criteria